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Food for Space Flight



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Astronaut Robert Crippen preparing meals on the first flight of the Space Shuttle Columbia.

Food for Space Flight

More than 20 years ago, astronaut John Glenn became the first American to orbit the Earth. His mission lasted nearly five hours and before splashing down in the Atlantic ocean, Glenn and his Mercury spacecraft completed three trips around the world.

Among the many tasks Glenn had to perform while in orbit were the first American space experiments in eating food in the weightless conditions of Earth orbit. Glenn's flight was too short to make eating a necessity but future flights were expected to last many days and even weeks. His experience would help design space food systems.

Eating in space for John Glenn turned out to be an easy though not too tasty experience. Before the flight, some experts were worried that, in weightlessness, food would be hard to swallow and as a result, collect in the throat. Glenn found that eating in space was relatively easy and once the food reached the mouth, there was no problem in swallowing. Other Mercury astronauts following John Glenn were forced to endure bite-sized cubes, freeze dried foods, and semi-liquids in aluminum toothpaste-type tubes. They found the food unappetizing, had trouble rehydrating the



Astronaut Joe H. Engle (second flight of Shuttle) prepares to fill an accordion-like drink container with a water gun. An already filled container is floating by his left knee.

freeze-dried foods, and disliked squeezing the tubes. Furthermore, crumbs from the bite-sized cubes had to be captured to prevent them from fouling instruments.

In the Gemini missions eating in space became more normal. The aluminum tubes of the

Mercury program were replaced because the container weighed more than the food inside. Bite-sized food chunks were coated with an edible gelatin to reduce crumbling. Rehydratables were encased in an improved plastic container. To rehydrate food, water was injected into the pack through the nozzle of a water gun. After kneading the contents the food became a puree and was squeezed through a tube into the astronaut's mouth.

Not only were the food containers for the Gemini astronauts improved but the menu selections were enlarged enough to provide four days of meals before repeating any menus. A typical meal would include shrimp cocktail, chicken and vegetables, toast squares, butterscotch pudding, and apple juice. Before each flight, meal combinations were chosen by the astronauts themselves but the menus chosen were required to provide 2,800 calories per day. To provide proper balance, 16 to 17 percent of the menu consisted of protein, 30 to 32 percent fat, and 50 to 54 percent carbohydrate.

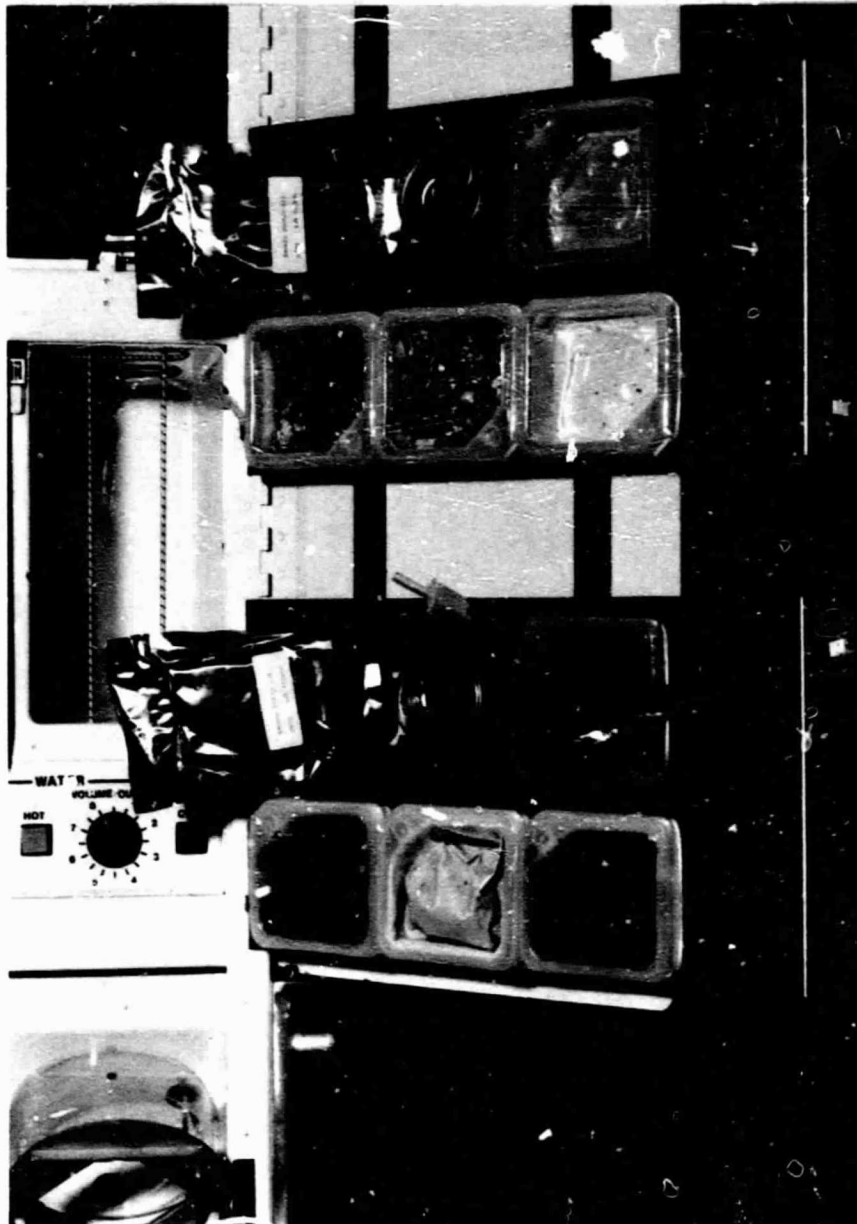
In the Apollo program, food packages were similar to those used in the Gemini missions but the variety of food was considerably greater. Apollo astronauts had the added luxury of heated water for hot drinks

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and hot foods at a temperature of 67 degrees C (154 degrees F) and chilled water at 7 degrees C (45 degrees F). Water temperatures from the dispenser of the Gemini spacecraft hovered at the 21 degrees C (70 degrees F) ambient spacecraft temperature. With hot water available, food was easier to rehydrate and much improved in taste.

Further advances in Apollo food systems came with the introduction of the "spoon-bowl" package for rehydratable foods and retort pouches for thermostabilized foods. Following rehydration of the contents in the spoon-bowl, a pressure type, plastic zipper was opened and the food removed with a spoon. The moisture content in the food enabled it to cling to the spoon. Food in the retort pouches was consumed as is.

In 1973 and 1974, the Skylab spacecraft was occupied by three teams of astronauts. Space food systems there were much improved over systems used in Apollo, Gemini, and Mercury. Unlike previous space vehicles for astronauts, Skylab featured a large interior volume and space was available for a dining room table. The table was a pedestal where food trays were mounted. When dining, the three-astronaut teams would "sit



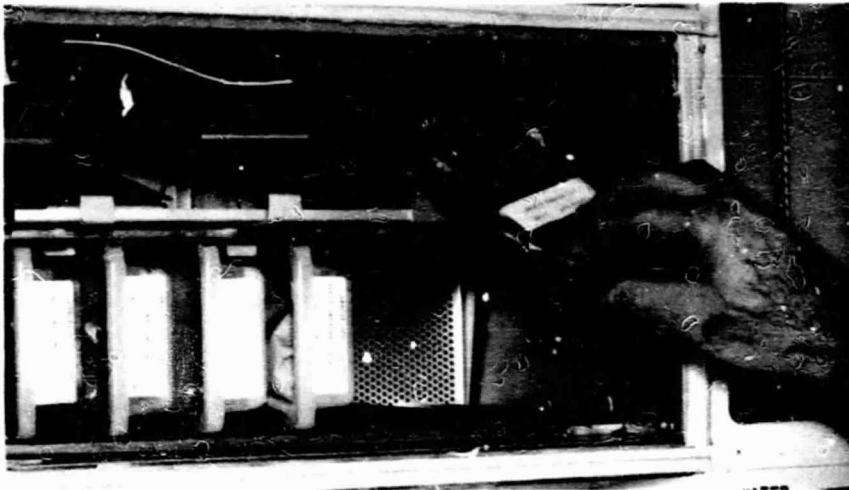
Two Shuttle operational meals before and after reconstitution.

down" in the air by means of foot and thigh restraints and eat in an almost normal fashion. The food trays not only held the food in place but also served as warming devices. Underneath three of eight cavities in the trays were warmers that could raise temperatures of foods needing heating to 66 degrees C (151 degrees F).

Food containers for the Skylab astronauts consisted of aluminum cans with full panel pull-out lids. Cans containing thermostabilized food had a built-in membrane to prevent

spillage when removing the lid in weightlessness. Rehydratable foods were in a plastic pouch within the can and had a water valve for rehydration. Canned, ready-to-eat foods were held in the can with a slit plastic cover. Instead of plastic drinking bags, Skylab drinking containers were collapsible bottles that expanded accordian style when filled with hot or cold water.

Eating on Skylab was a fairly normal operation. Knife, fork, and spoon were held magnetically to the food tray until needed. A pair of scissors



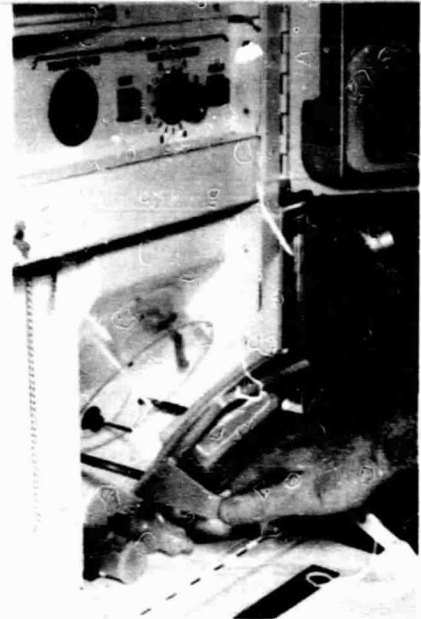
Food in a retort pouch is about to be inserted into the convection oven of the Shuttle's galley for heating. Vegetables and soups in plastic containers can be heated in the oven.

was added to the usual utensils for cutting open the plastic membranes. With careful use of the utensils, food would remain in the cans until needed. On occasion however, a too rapid motion with a fork or spoon would cause a piece of meat or other food to drift away from the tray.

Because of its relatively large storage space, Skylab was able to feature an extensive menu of 72 different food items. Unique to Skylab was a freezer for foods such as filet mignon and vanilla ice cream and a refrigerator for chilling fruits and beverages. Enough food was carried to provide each astronaut with 1.9 kilograms (4.2 pounds) of food per day. This weight also included the weight of the primary food packaging.

In 1975, the last of the Apollo flights took place with the Apollo-Soyuz docking mission. The Apollo spacecraft did not have the freezer that Skylab featured but many of the food advances from Skylab and the earlier Apollo missions were incorporated. Because of the

short duration of the flight (nine days), many short shelf-life items were added to the foods carried. Fresh breads and cheese were included as a part of 80 different varieties of food dined upon by the Apollo astronauts. Many foods were packaged in plastic in bite-sized portions while others were placed in spoon-bowl packages or plastic drinking bags. To make eating easier, a food tray was carried on the mission. The tray did not warm the food as the Skylab



A plastic food container about to be injected with 6 ounces of water. The package is pushed into the galley where a large gauge hollow needle will automatically puncture the lid for water injection.

tray did, but it held the food in place with springs and Velcro® fasteners. The tray was secured to the crewmember's leg during meal time.

Space Shuttle Food System

NASA's Space Shuttle has opened a new era in space travel. The Shuttle takes off as a

Space Shuttle Menu Design

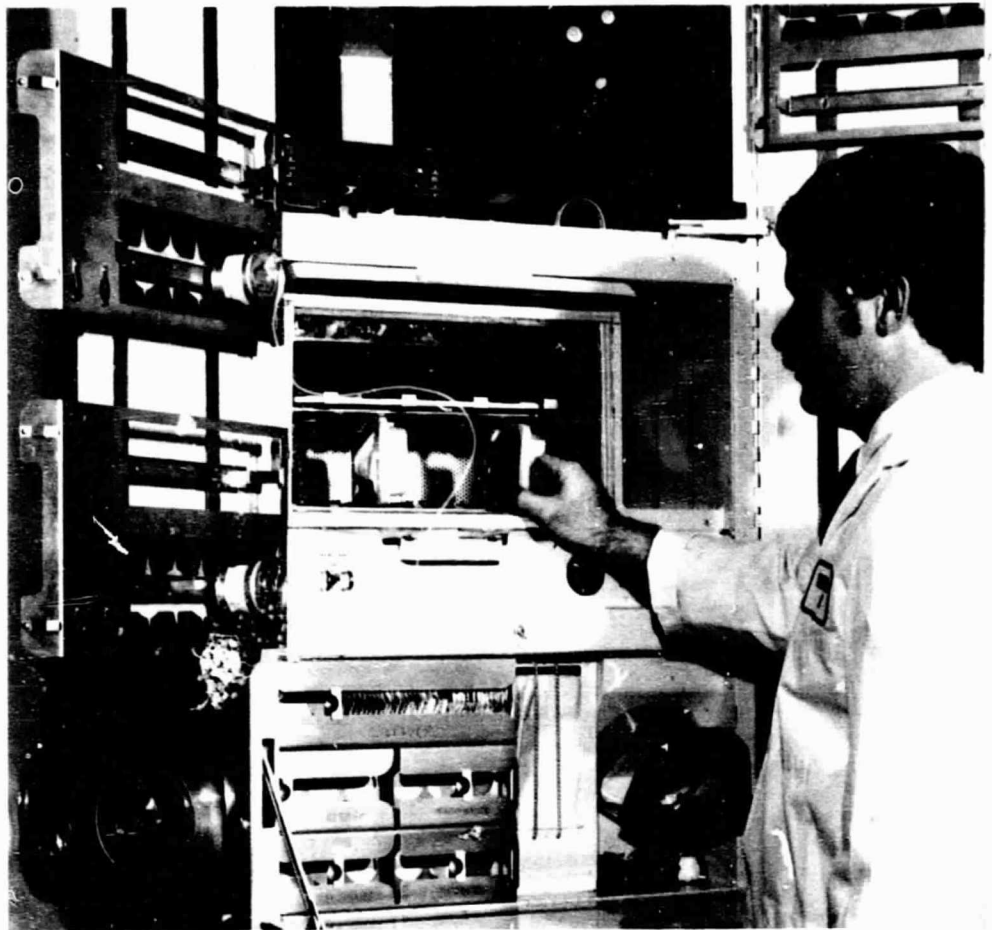
The Shuttle menu is designed to provide nutrition and energy requirements essential for good health and effective performance with safe, highly acceptable foods. In order to maintain good nutrition, the menu will provide at least the following quantities of each nutrient each day:

Protein	(g)	56	Vitamin B ₁₂	(g)	3.0
Vitamin A	(iu)	5000	Calcium	(mg)	800
Vitamin D	(iu)	400	Phosphorous	(mg)	800
Vitamin E	(iu)	15	Iodine	(μg)	130
Ascorbic Acid	(mg)	45	Iron	(mg)	18
Folacin	(μg)	400	Magnesium	(mg)	350
Niacin	(mg)	18	Zinc	(mg)	15
Riboflavin	(mg)	1.6	Potassium	(meq)	70
Thiamine	(mg)	1.4	Sodium	(meq)	150
Vitamin B ₆	(mg)	2.0			

rocket, orbits the Earth as a spacecraft, and lands as an airplane. Missions on the Shuttle will last from one to 30 days for crews of two to seven astronauts.

To meet the nutritional needs of Shuttle crews, a new food system has been developed. This system centers around a galley that has been installed on the mid-deck of the Orbiter's cabin. The galley is a modular unit that can be removed for special flight missions that require extra interior space. It features hot and cold water dispensers, a pantry, an oven, food serving trays, a personal hygiene station, a water heater, and auxiliary equipment storage areas. The galley does not have a freezer as in Skylab, nor a refrigerator.

Preparation of a meal on the Shuttle is started by a crewmember 30 to 60 minutes before mealtime. A full meal for a crew of four can be set up in about five minutes. Heating and reconstitution of the food takes an additional 20 to 30 minutes. The "chef" removes complete meal packages from storage and makes the necessary preparations before serving. Food needing rehydration is given hot or cold water in pre-measured amounts. Water for rehydration comes from the Orbiter's fuel cells that produce electricity by combining hydrogen and oxygen gas. Since water is a usable byproduct from the fuel cells, much weight can be saved by sending up food in a dried form for rehydration in space. To simplify food packaging a new rehydratable food pack design is used. The bottom of the package is an injection-molded,



A mockup of the galley that will fly on Space Shuttle Orbiters during most operational flights. A technician is inserting a food package into the convection oven. Empty food trays are attached to the doors while food is being prepared. The plastic hemisphere attached to the left side is a hand wash hygiene station.

high density polyethylene base. A thermoformed flexible lid made of plastic film covers the top. To add water, a large gauge hollow needle is inserted through a septum in the base.

Food needing heating is placed in a forced air convection oven, a new feature for space flight. The maximum temperature of the oven is 82 degrees C (180 degrees F) and it can hold temperatures at 65 degrees C (150 degrees F) for an extended period. The oven can heat containers of different sizes and shapes.

Beverage containers for the Shuttle are identical to the packages for rehydratables. A polyethylene straw is inserted through the same septum that is used for injecting water. When not in use, a clamp closes the straw.

While the astronauts are eating, food containers are held in a food tray that is attached to a table in the mid-deck, to the astronaut's lap while seated, or attached to a wall. Eating utensils consist of a knife, fork, spoon, and a pair of scissors for cutting open packages. Food

Space Shuttle Food and Beverage List

Foods*

Applesauce (T)	Chicken and noodles (R)	Peach ambrosia (R)
Apricots, dried (IM)	Chicken and rice (R)	Peaches, dried (IM)
Asparagus (R)	Chili mac w/beef (R)	Peaches, (T)
Bananas (FD)	Cookies, pecan (NF)	Peanut butter
Beef almonline (R)	Cookies, shortbread (NF)	Pears (FD)
Beef, corned (I) (T)	Crackers, graham (NF)	Pears (T)
Beef and gravy (T)	Eggs, scrambled (R)	Peas w/butter sauce (R)
Beef, ground w/pickle sauce (T)	Food bar, almond crunch (NF)	Pineapple, crushed (T)
Beef jerky (IM)	Food bar, chocolate chip (NF)	Pudding, butterscotch (T)
Beef patty (R)	Food bar, granola (NF)	Pudding, chocolate (R) (T)
Beef, slices w/barbeque sauce (T)	Food bar, granola/raisin (NF)	Pudding, lemon (T)
Beef steak (I) (T)	Food bar, peanut butter/	Pudding, vanilla (R) (T)
Beef stroganoff w/noodles (R)	granola (NF)	Rice pilaf (R)
Bread, seedless rye (I) (NF)	Frankfurters (Vienna sausage) (T)	Salmon (T)
Broccoli au gratin (R)	Fruitcake (NF)	Sausage patty (R)
Breakfast roll (I) (NF)	Fruit cocktail (T)	Shrimp creole (R)
Candy, Life Savers*, assorted	Green beans, french	Shrimp cocktail (R)
flavors (NF)	w/mushrooms (R)	Soup, cream of mushroom (R)
Cauliflower w/cheese (R)	Green beans and broccoli (R)	Spaghetti w/meatless sauce (R)
Cereal, bran flakes (R)	Ham (I) (T)	Strawberries (R)
Cereal, cornflakes (R)	Jam/Jelly (T)	Tomatoes, stewed (T)
Cereal, granola (R)	Macaroni and cheese (R)	Tuna (T)
Cereal, granola w/blueberries (R)	Meatballs w/barbeque sauce (T)	Turkey and gravy (T)
Cereal, granola w/raisins (R)	Nuts, almonds (NF)	Turkey, smoked/sliced (I) (T)
Cheddar cheese spread (T)	Nuts, cashews (NF)	Turkey tetrazzini (R)
Chicken a la king (T)	Nuts, peanuts (NF)	Vegetables, mixed Italian (R)

Beverages

Apple drink	Instant breakfast, vanilla
Cocoa	Lemonade
Coffee, black	Orange drink
Coffee w/cream	Orange-grapefruit drink
Coffee w/cream and sugar	Orange-pineapple drink
Coffee w/sugar	Strawberry drink
Grape drink	Tea
Grapefruit drink	Tea w/lemon and sugar
Instant breakfast, chocolate	Tea w/sugar
Instant breakfast, strawberry	Tropical punch

Condiments

Barbeque sauce
Catsup
Mustard
Pepper
Salt
Hot pepper sauce
Mayonnaise

*Abbreviations in parentheses indicate type of food: T = thermostabilized, I = irradiated, IM = intermediate moisture, FD = freeze dried, R = rehydratable, and NF = natural form.

can be seasoned with serving-sized packets of mustard, catsup, mayonnaise, hot sauce, and liquified salt and pepper. Following the meal, food containers are discarded and the utensils and serving trays are cleaned with "wet wipes."

Shuttle Menu

The Space Shuttle menu currently features more than 70 food items and 20 beverages. Shuttle travelers will have a varied menu every day for six

days rather than the personal preference meals used in previous space missions. Each day, three meals are allowed, with a repeat of menus after six days. The pantry also provides plenty of foods for snacks and between meal beverages and for individual menu changes. The pantry also stores additional contingency food to last 96 hours.

Food System Constraints

The primary objective in

designing a food system for the Space Shuttle is to provide food that is safe and nutritious, light in weight and compact, and is packaged in a convenient form that allows easy manipulation in the weightless environment of an orbiting spacecraft. To achieve this objective requires a careful consideration of three important factors: biological, operational, and engineering. Under each factor are many constraints that affect the final choice of food and how it is

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Typical Menu for the First Four Shuttle Flights*,†

DAY 1	DAY 2	DAY 3	DAY 4
Peaches (T) Beef patty (R) Scrambled eggs (R) Bran flakes (R) Cocoa (B) Orange drink (B)	Applesauce (T) Beef jerky (NF) Granola (R) Breakfast roll (I) (NF) Chocolate, instant breakfast (B) Orange-grapefruit drink (B)	Dried peaches (IM) Sausage (R) Scrambled eggs (R) Cornflakes (R) Cocoa (B) Orange-pineapple drink (B)	Dried apricots (IM) Breakfast roll (I) (NF) Granola w/blueberries (R) Vanilla instant breakfast (B) Grapefruit drink (B)
Frankfurters (T) Turkey tetrazzini (R) Bread (I) (NF) Bananas (FD) Almond crunch bar (NF) Apple drink (B)	Corned beef (T) (I) Asparagus (R) Bread (I) (NF) Pears (T) Peanuts (NF) Lemonade (B)	Ham (T) (I) Cheese spread (T) Bread (I) (NF) Green beans and broccoli (R) Crushed pineapple (T) Shortbread cookies (NF) Cashews (NF) Tea w/lemon and sugar (B)	Ground beef w/pickle sauce (T) Noodles and chicken (R) Stewed tomatoes (T) Pears (FD) Almonds (NF) Strawberry drink (B)
Shrimp cocktail (R) Beef steak (T) (I) Rice pilaf (R) Broccoli au gratin (R) Fruit cocktail (T) Butterscotch pudding (T) Grape drink (B)	Beef w/barbeque sauce (T) Cauliflower w/cheese (R) Green beans w/mushrooms (R) Lemon pudding (T) Pecan cookies (NF) Cocoa (B)	Cream of mushroom soup (R) Smoked turkey (T) (I) Mixed Italian vegetables (R) Vanilla pudding (T) (R) Strawberries (R) Tropical punch (B)	Tuna (T) Macaroni and cheese (R) Peas w/butter sauce (R) Peach ambrosia (R) Chocolate pudding (T) (R) Lemonade (B)

*Abbreviations in parentheses indicate type of food: T = thermostabilized, I = irradiated, IM = intermediate moisture, FD = freeze dried, R = rehydratable, NF = natural form, and B = beverage.
†Beginning with the fifth Shuttle flight, the menu cycle will be enlarged to six days.

packaged.

The biological factor in food design requires the food to be both safe and nutritious. It should also appeal to the crew's sensory preferences. The food must be easy to ingest and digest and not cause any hygiene or gastroenterological problems.

The operational factor relates both to the food and the nature of its packaging. The package must be light in weight (engineering factor) but provide for protection and stability of the food in storage for periods that might last well over 30 days. Food must be easy to prepare and require little crew attention. Easy disposal of waste food and used packaging material is



Astronaut Robert Crippen (first flight of Shuttle) eats from a bowl and spoon pack while on board the Space Shuttle Columbia.

another constraint.

The engineering factor has to do with not only the weight of the food and packaging but how compact it is for storage. Thirty day missions of the Shuttle will require large amounts of food. The food and packaging must survive the temperature, pressure, acceleration, and vibration of a Shuttle flight. Still another constraint is the quantity of water needed for rehydration.

Shuttle Food and Beverage List

Thermostabilized (T): Heat processed foods ("off-the-shelf" items) in aluminum or bimetallic tins and retort pouches.

Irradiated (I): Foods preserved



A complete meal for Space Shuttle astronauts. Plastic, metal, and foil food containers are held in an aluminum meal tray by friction. This meal consists of smoked turkey (foil bag) mixed Italian vegetables, mushroom soup, strawberries, butterscotch pudding (can), and tropical fruit punch.

by exposure to ionizing radiation and packed in flexible foil-laminated pouches.

Intermediate Moisture (IM):

Dried foods with a low moisture content such as dried apricots. Packed in flexible plastic pouches.

Freeze Dried (FD): Foods that are prepared to the ready-to-eat stage, frozen and then dried in a freeze dryer which removes the water by sublimation. Freeze dried foods such as fruits may be eaten as is while others require the addition of hot or cold water before consumption.

Rehydratable (R): Dried foods and cereals that are

rehydrated with water produced by the Shuttle Orbiter's fuel cell system. Packed in semi-rigid plastic container with septum for water injection.

Natural Form (NF): Foods such as nuts, crunch bars, and cookies. Packed in flexible plastic pouches.

Beverages (B): Dry beverage powder mixes packed in rehydratable containers.

As more experience in spaceflight is gained, food systems for space travelers will continue to improve. New foods are being developed and evaluated along with new commercial foods as candidates for the Shuttle food system. Foods are tested for taste,

nutritional value, convenience in preparation, storage life, and microbiological safety. The containers for the foods and preparation techniques are also being evaluated.

While the science of space nutrition is still relatively young, potential benefits to people on Earth will certainly arise from it. Already, the technology originally developed for spacefoods has found its way into the food market place. Space nutrition research may also help in understanding the problems of deterioration of people restricted to hospitals and nursing homes. The weightless condition of Earth orbit effects the body in much the same way as extended bed rest.